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Fungal communities of volcanic ash soils along an altitudinal gradient in Mexico

III. Seasonal variation

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With one figure

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1. Introduction

In recent years several detailed studies have been carried out on the seasonality of soil microfungi (BISSETT & PARKINSON, 1979; WIDDEN, 1986). They revealed no clear seasonal trends in fungal composition and proposed that site effects were the major source of variation in mycofloras. WIDDEN (1986), however, points out that it could be found the same species collected under different extreme conditions. GOCHENAUR (1978), after analysing numerous samples, taken over a two-year period, found that the abundance of propagules of several species showed marked seasonal variation. CHRISTENSEN (1969) stated that seasonality in soil microfungal composition is more evident in extreme climatic conditions. In a previous study (RODRIGUEZ *et al.*, in press) the composition and organization of the fungal communities in soils of three sites located along an altitudinal gradient was analyzed. The present study attempts to illustrate the seasonal variation in the composition and abundance of the propagules of the major species of these 3 fungal communities through an analysis of A0 soil samples taken during 3 clearly distinguishable seasons: the rainy season, the post-rainy season and the dry season.

2. Study area

Three sites were selected on an altitudinal gradient along the western wall of Popocatepetl volcano, southeast of Mexico Valley. A description of the vegetation at the sites has been given previously (RODRIGUEZ *et al.*, 1990).

The climate of the 3 sites is characterized by a rainy summer and a dry winter (fig. 1) and the total rainfall at the three sites is very similar. There are only small variations in mean monthly temperatures at these sites, however at La Joya the winter is colder and longer. It should be emphasized that at La Joya the minimum temperatures between September and March varies between – 2.0 and 0 °C. Hence at this site during February and March the ground water is frozen. In Nexpayantla and La Tijera, on the other hand, the soil remains dry. So in the latter cases water is not available for biological activity.

The soils of the 3 sites have originated from volcanic ashes. The geochemical and biochemical characteristics of the soils, vegetation and climate of the 3 sites have been described in detail previously (BETTUCCI, 1983).

3. Materials and methods

Four replicates of soil samples were taken from each site on 3 different occasions during 1983: in March during the dry season, in July during the peak of the rainy season and in November, 2 months after the end of the rainy season. The dilution plate method for soil fungi analysis was carried out as described by RODRIGUEZ *et al.* (1990). The A0 horizon fungal population of each season were compared using Steinhause's Index of similarity: IS = 1/2 (W/A = W/

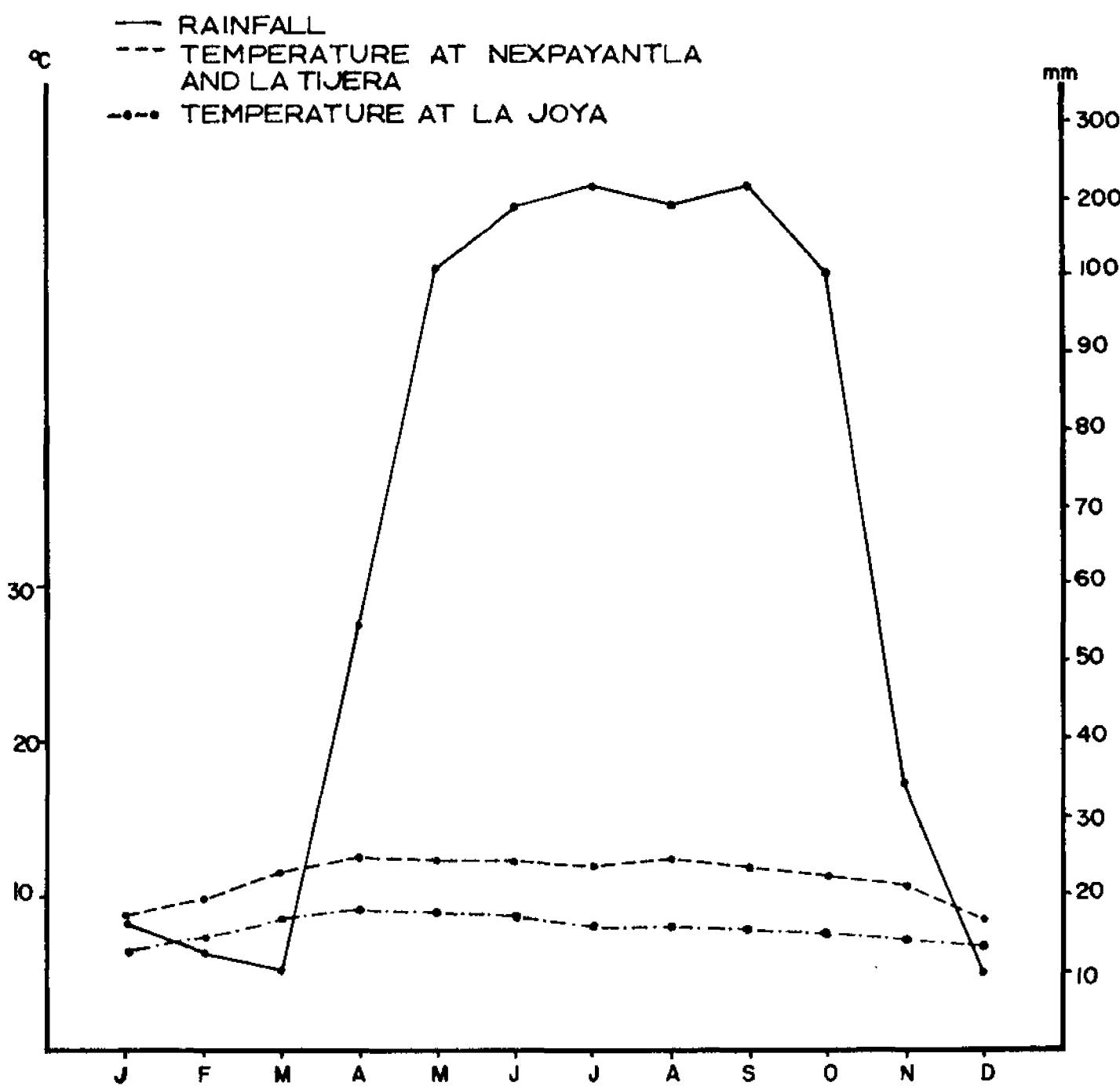


Fig. 1. Rainfall and mean monthly temperature distribution.

B) where A is the sum of the abundance of all species during one season, B is the sum in the other season and W represents the sum of the minimum abundances of the shared species (LEGENDRE & LEGENDRE, 1979). In order to standardize the abundance of a species for all 3 seasons, the number of species for 100 isolates was calculated.

4. Results

One general trend that was evident from seasonal data was that the overall abundance of soil microfungi, as reflected by the total number of species, were not stable at each site for the 3 seasons (table 1). For 2 sites (Nexpayantla and La Tijera) the overall abundance decreased in March and the

Table 1. Seasonal variation in total number of propagules and number of species/100 isolates of fungal communities at La Joya (LJ), Nexpayantla (N) and La Tijera (LT).

Season	Nº of propagules/g dry soil			Nº of species/100 isolates		
	LJ	N	LT	LJ	N	LT
Dry (March)	105,500	124,500	186,000	4.26	6.24	3.76
Rainy (July)	16,500	242,000	439,000	42.42	2.65	1.59
Post-rainy (November)	25,500	208,000	263,000	25.49	1.68	2.09
Yearly average	49,167	191,500	296,000	24.06	3.58	2.48

number of species increased. Conversely in the remaining site the number of propagules increased and the number of species decreased considerably.

To all 3 sites one set of species was constant, i.e., they were isolated at every season. Among

Table 2. Seasonal distribution of fungal taxa along an altitudinal gradient (n^o of propagules/g dry soil $\times 10^3$).

Site La Joya	Dry March	Rainy July	Post-rainy November
<i>Oidiodendron periconioides</i> MORRALL	32	1	20
<i>Penicillium chrysogenum</i> THOM	3	2	1
<i>Penicillium turbatum</i> WESTLING	5	2	
<i>Cladosporium herbarum</i> (PERS.) LINK ex GRAY	1		4
<i>Penicillium nigricans</i> BAIN. ex THOM (strain 17)	71		4
<i>Phialophora lagerbergii</i> (MELIN et NANNF) CONANT	9		4
<i>Phialophora mustea</i> NEERGAARD		12	2
Basidiomycete		5	2
<i>Eupenicillium lasseni</i> PADDEN	11		
<i>Oidiodendron echinulatum</i> BARRON	61		
<i>Penicillium nigricans</i> BAIN. ex THOM (strain 10)	18		
<i>Epicoccum</i> sp.		2	
<i>Eupenicillium pinetorum</i> STOLK		1	
<i>Oidiodendron</i> sp. 1		1	
<i>Penicillium claviforme</i> BAINIER		1	
<i>Penicillium decumbens</i> THOM		1	
<i>Penicillium frequentans</i> WESTLING		1	
<i>Penicillium</i> sp. 1		2	
<i>Penicillium</i> sp. 9		1	
Hyaline mycelium with sclerots		1	
<i>Eladia saccula</i> (DALE)SMITH			1
<i>Mucor hiemalis</i> WEHMER			4
<i>Penicillium</i> sp. 10			1
<i>Phialophora fastigiate</i> (LAGERB. et MELIN)CONANT			1
<i>Trichoderma viride</i> PERS. ex GRAY			3
Sterile hyaline mycelium 508			4
Total isolates	211	33	51

these some showed a highly significant increase in propagules during the rainy or post rainy season; others increased in the dry season. Another group of species showed an intermittent pattern: they were isolated only during 2 seasons. Some of them peaked during the dry season and the others during the rainy or post-rainy season. The remaining species were isolated only during one season. It was also observed the several species behave in different ways depending on the site.

At La Joya only two species were constant: *O. periconioides* and *P. chrysogenum*. The former peaked in the dry season while the later remained nearly unchanged. However *O. periconioides* was a major species and *P. chrysogenum* was a minor one. Among the intermittent species, *P. nigricans* strain 17 increased its abundance during the dry season. A large number of rare species were isolated only during the rainy or post-rainy season. A lesser number of species such as *O. echinulatum*, *E. lasseni* and *P. nigricans* strain 10 were found only in the dry season. The number of species isolated only during one season was very high, i.e. 70 % of the total number of the species (table 2).

Therefore the indices of similarity between different seasons were very low, especially between the dry and rainy seasons (table 3).

At Nexpayantla 2 of the 4 constant species (*P. nigricans* strain 17 and *T. viride*) increased the abundance during the rainy or post rainy season. *P. griseum* peaked in the dry season and *P. chrysogenum* remained nearly unchanged. Only one of the three intermittent species, *E. lasseni*, which peaked in the dry season was a major one as it represented nearly 25 % of the total isolates in this month. The species isolated only during the dry or rainy season constituted 64 % of the total species. Among them, *H. grisea*, a rainy season species was the only important one. Only 2 species were exclusively isolated during the post-rainy season (table 2). The indices of similarity were markedly different: 17.7 % between the dry and rainy seasons and 75 % between the rainy and post-

Table 2. (continued)

Nexpayantla	Dry March	Rainy July	Post-rainy November
<i>Penicillium chrysogenium</i> THOM	2	6	1
<i>Penicillium griseum</i> (SOPP)THOM	105	22	38
<i>Penicillium nigricans</i> BAIN. ex THOM (strain 17)	28	345	301
<i>Trichoderma viride</i> PERS. ex GRAY	3	17	60
<i>Eupenicillium pinetorum</i> STOLK	8	10	
<i>Penicillium turbatum</i> WESTLING	2	1	
<i>Eupenicillium lasseni</i> PADDEN	61		10
<i>Eupenicillium anatolicum</i> STOLK	1		
<i>Gliomastix murorum</i> (CORDA) HUGHES	2		
<i>Penicillium frequentans</i> WESTLING	5		
<i>Penicillium janthinellum</i> BIOURGE (strain 133)	7		
<i>Penicillium shearrii</i> STOLK et SCOTT	4		
<i>Penicillium stolkiae</i> SCOTT	3		
<i>Phialophora lagerbergii</i> (MELIN et NANNF) CONANT	12		
<i>Talaromyces flavus</i> (KLÖCKER) STOLK et SAMSON	4		
Sterile hyaline mycelium 1	2		
<i>Acremonium tubakii</i> GAMS		1	
<i>Humicola grisea</i> TRAAEN		53	
<i>Oidiodendron echinulatum</i> BARRON		20	
<i>Oidiodendron periconioides</i> MORRALL		5	
<i>Penicillium decumbens</i> THOM		1	
<i>Penicillium</i> sp. 8		2	
Sterile hyaline mycelium 3		1	
<i>Penicillium purpurogenum</i> STOLL			4
<i>Phialophora mustea</i> NEERGAARD			2
Total isolates	249	484	416

rainy seasons (table 3). This high similarity in the latter case may be explained because, first, during these months the most abundant species was the same one (*P. nigricans* strain 17), and in each season it represented 70 % of the isolates. Secondly, the number of species isolated only during the post-rainy season was very low.

At La Tijera, *O. periconioides*, *P. nigricans* strain 17, *P. purpurogenum*, *E. pinetorum* and *T. viride* were isolated during every season. *O. periconioides* (the dominant species), *P. nigricans* strain 17 and *P. purpurogenum* increased their abundance during the rainy season. *E. pinetorum* and *T. viride* showed a clear increase during the post-rainy season. The intermittent species *P. frequentans* clearly peaked in the rainy season; *P. janthinellum* strain 139 and *P. griseum* peaked in the dry season and *P. janthinellum* strain 133 remained essentially unchanged. The number of species isolated during only one season was lower than at the other sites (56.5 % of the total species). All of them were rare species except *P. nigricans* strain 10 in the dry season and *E. lasseni* and *O. tenuissimum* in the post-rainy season (table 2). In contrast to other sites the similarity among the seasons did not vary much. The index of similarity between the dry season and the rainy season fungal communities was much higher than in the other sites because the number of shared species was greater and included the dominant species (table 3).

The indices of similarity between La Joya and the other two sites during the same season were very low, the highest being observed in the dry season. The similarities between Nexpayantla and La Tijera were similar, but slightly lower in the rainy season (table 4).

Table 2. (continued)

La Tijera	Dry March	Rainy July	Post-rainy November
<i>Eupenicillium pinetorum</i> STOLK	7	31	50
<i>Oidiiodendron periconioides</i> MORRALL	141	595	290
<i>Penicillium nigricans</i> BAIN. ex THOM (strain 17)	31	80	44
<i>Penicillium purpurogenum</i> STOLL	12	39	23
<i>Trichoderma viride</i> PERS. ex GRAY	7	19	53
<i>Penicillium frequentans</i> WESTLING	3	41	
<i>Penicillium janthinellum</i> BIOURGE (strain 133)	49	53	
<i>Penicillium janthinellum</i> BIOURGE (strain 139)	21	1	
<i>Penicillium griseum</i> (SOPP) THOM	18	1	
<i>Paecilomyces</i> sp.		13	7
<i>Penicillium nigricans</i> BAIN. ex THOM (strain 10)	79		
<i>Penicillium terrestre</i> JENSEN	1		
<i>Penicillium</i> sp. 1	1		
<i>Penicillium</i> sp. 2	1		
Sterile hyaline mycelium 2	1		
<i>Penicillium</i> sp. 4		1	
<i>Penicillium</i> sp. 5		2	
<i>Penicillium</i> sp. 7		2	
Sterile dark mycelium 3		1	
<i>Eupenicillium lasseni</i> PADDEN			32
<i>Oidiiodendron tenuissimum</i> (PECK) HUGHES			20
<i>Penicillium chrysogenum</i> THOM			3
Sterile hyaline mycelium 508			3
Total isolates	372	878	526

Table 3. Indices of similarity between different seasons.

	La Joya	Nexpayantla	La Tijera
March–July	4.10	17.73	40.16
July–November	14.29	75.77	58.97
November–March	22.90	24.06	44.32

Tables 4. Indices of similarity between different sites, during the same season.

	March	July	November
La Joya Nexpayantla	22.60	1.92	2.99
Nexpayantla La Tijera	21.25	16.44	22.92
La Tijera-La Joya	27.78	0.65	9.8

5. Discussion

The data show that at all three sites the abundance of propagules in the communities, as well as in the individual populations presented a clear response to seasonal variations. Furthermore, the similarities between season increased as altitude decreased. The seasonal changes in temperature were higher at La Joya than at the lower sites. In the latter probably only rainfall determined the seasonal variation in fungal communities while at La Joya, besides rainfall, low temperatures during the dry season (freezing the soil) intervened. The index of similarities used permits the comparison of the composition and organization in the samples taken at different seasons.

At La Joya the low indices of similarity observed provide evidence that these parameters do not remained constant throughout the year. The major species in the March and July samples were not the same ones. However nearly all of them were isolated in the November sample, although less abundantly. Beginning in October the minimum temperature recorded at this site was 0 °C and rain started to decrease. Probably the transitional weather conditions during the month of November favoured the development of species adapted to the cold, but which has been not responded favourably to the precipitation of the previous month.

At Nexpayantla the high index of similarity observed between the samples taken in July and November contrasted with the low indices observed when these months are compared to the March sample. Although the mean monthly temperature did not vary significantly throughout the year and the minimum temperature was always above 0 °C, the rain during the months prior to the March sample amounted to only 7.2 % of annual rainfall. This may explain the variation in composition and organization of the populations of the dry season with respect to those of the wet months. *P. nigricans* strain 17, the dominant species during the wet seasons, did very poorly under dry conditions. *P. griseum* and *E. lasseni*, on the other hand, dominated during the dry season.

At La Tijera, variations in temperature and rainfall were similar to those at Nexpayantla. As at the latter site, here the highest index of similarity was observed between the rainy season and the post-rainy season, but the indices of similarity between the dry season and the wet ones were also high and did not differ significantly from one another. These high similarities reflect a major consistency in the composition and organization of the community. Thus, *O. periconioides* was the dominant species in all 3 seasons, accounting for 38 to 68 % of the propagules. Although this species did best during the season of maximum precipitation, it retained its dominance in the community throughout the year, which would indicate its greater capacity to adapt to extreme conditions in comparison with the other populations. The increase in the number of propagules of *O. periconioides* in the rainy season coincided with the increase observed in the population of mites which aid in the distribution of spores (MANGENOT & REISINGER, 1976). Several minor species were also found in all three seasons, and in every case they were encouraged by the wet conditions. GRIFFIN (1973) considered that the increase in soil moisture promotes the development of some species with high competitive ability. Hence fungistasis on other species with lower saprophytic ability was produced. Then the effect in competition would be accentuated and some species would expand their niche while others would be reduced to a peripheral position (GOCHENAUER, 1978).

Of the 49 species isolated some seemed to thrive exclusively in the wet seasons. Among them *Ph. mustea*, *H. grisea*, *T. viride*, *P. purpurogenum* and an unidentified Basidiomycete were the most important. Another set of species (such as *P. nigricans* strain 10, *P. griseum*, *P. janthinellum* strain 139 and *Ph. lagerbergii*) seemed to be adapted to "extreme" conditions, both of cold and dryness and could be considered as survivors or escapers (WIDDEN, 1986). CHRISTENSEN (1969) pointed out that microfungal seasonality may be expected when vegetation and soil environment show marked seasonal variation. In Mexico, located in the tropical region, sharp differences in climatic conditions along an altitudinal gradient can be observed during the year. The alternation of rainy and dry seasons appears to cause shifts in the abundance of individual populations as well as in the composition of the community and the replacement of dominant species. On the other hand, at each site species were found benefited from cold or dry conditions but which seem to have adapted to wet conditions at another site. Such species included *E. lasseni*, *O. echinulatum*, *O. periconioides*, *P. frequentans* and *P. nigricans* strain 17. As suggested previously (RODRIGUEZ *et al.*, 1990), the species common to more than one site exhibit different interactions in each site, thus giving rise to different fungal communities; so one would expect different responses on the part of the same species to similar climatic conditions. BISSETT & PARKINSON (1979) in an extensive analysis of fungi from alpine soil, and WIDDEN (1986) in a similar study of soil fungi from southern Quebec, found that site factors were the major source of variation, although seasonal effects were significant. On an altitudinal gradient, WIDDEN (1987) found that closely related species of *Penicillium* and *Trichoderma* exhibited differences in their response to an environmental gradient. It is probable therefore, that the apparently divergent behavior of certain species, which peaked at one site decreased at another during the same season, could be interpreted as a result of weather-site interaction effects.

6. Résumé

[Communautés fongiques isolées des sols volcaniques au Mexique selon un gradient altitudinal. III. Variation saisonnière]

Cette étude est une analyse des variations des populations fongiques de sols prélevés sur le flanc du volcan Popocateptl (Mexico) en trois sites, en trois saisons différentes. Les indices de similitudes entre les saisons se sont révélés très bas mais ils augmentent au fur et à mesure que l'altitude décroît. D'une façon générale, l'abondance des champignons est variable à chaque site, aux trois saisons. Dans deux sites, l'abondance décroît en période sèche tandis que le nombre des propagules augmente mais celui des espèces décroît nettement. *Humicola grisea*, *Penicillium purpurogenum*, *Phialophora mustea*, *Trichoderma viride* et un Basidiomycète sont favorisés par un temps humide. *P. griseum*, *P. janthinellum*, *P. nigricans* (souche 10) et *Ph. lagerbergii* le sont par des conditions extrêmes (sécheresse ou froid). *Eupenicillium lasseni*, *Oidiodendron echinulatum*, *O. periconioides*, *P. frequentans* and *P. nigricans* (souche 17) ont une abondance inverse aux différents sites, selon les saisons, traduisant une interaction possible entre ces variables.

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Synopsis: Original scientific paper

BETTUCCI, L., C. RODRIGUEZ, & M. F. ROQUEBERT, 1990. Fungal communities of volcanic ash soils along an altitudinal gradient in Mexico. III. Seasonal variation. Pedobiologia **34**, 61–67.

A study was made on the seasonal variation in the composition and abundance of propagules of the fungal communities in the A0 horizon of 3 volcanic ash soils on the western slope of the volcano Popocatepetl (Mexico Valley). The indices of similarity of fungal communities between seasons were very low, but they increased as altitude decreased. One general trend evident from seasonal data was that the overall abundance of soil microfungi, as reflected by the total number of propagules and the number of species, were not stable at each site for the three seasons. For two sites (Nexpayantla and La Tijera) the overall abundance decreased in March and the number of species increased. Conversely, in the remaining site (La Joya) the number of propagules increased and the number of species heavily decreased.

Humicola grisea, *Penicillium purpurogenum*, *Phialophora mustea*, *Trichoderma viride* and an unidentified Basidiomycete appeared to benefit from wet weather. *P. griseum*, *P. janthinellum* strain 139, *P. nigricans* strain 10 and *Ph. lagerbergii* were apparently favored by extreme conditions (cold in La Joya, dryness in Nexpayantla and La Tijera). *Eupenicillium lasseni*, *Oidiodendron echinulatum*, *O. periconioides*, *P. frequentans* and *P. nigricans* strain 17 showed inverted patterns of distribution in their abundance at the different sites revealing a weather-site interaction effect.

Key words: Soil fungi, seasonal variation, volcanic ash soils.

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